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NICOTINE DUST FOR CONTROL OF TRUCK-CROP INSECTS

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OUTBREAKS OF INJURIOUS INSECTS, particularly aphids and thrips, are often serious handicaps to the growing of vegetable and truck crops. These have been hitherto combated mainly by the application of contact liquid sprays, the one most commonly used being nicotine sulphate. Because of several objections to this method of control, however, the practice of applying nicotine in a dust carrier has recently been adopted to a considerable extent, especially in California, as well as in other States.

This bulletin gives the reasons for adopting nicotine dust and tells of what it is composed, the proper time and method of application, and the strength to use. Different types of dusting machinery are described, and the work for which they are best adapted is indicated. Information is given for the treatment of the onion thrips, cucumber beetles, the melon aphis, cabbage aphis, and pea aphis, and the possibility of the control of similar insects on other crops is mentioned.

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NICOTINE DUST FOR CONTROL OF TRUCK-CROP INSECTS.

ROY E. CAMPBELL,

Assistant Entomologist, Truck-Crop Insect Investigations, Bureau of Entomology.

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REASONS FOR ADOPTING NICOTINE DUST.

AN INSECTICIDAL DUST has several advantages over a liquid spray. It can be applied much more easily and quickly than a spray, and a dust hopper can be refilled in much less time than a spray tank. The dust particles reach more insects than the spray, particularly on the undersides or in curled leaves. Power dusters cost less than power sprayers, while hand dusters are easier to carry and to operate than hand sprayers. Usually much less than 100 pounds of dust is required to cover an acre, while to spray the same area requires at least 100 gallons, weighing 800 pounds; on this account dusters can be operated on wet ground and side hills inaccessible to sprayers. For spraying with nicotine sulphate, a soap spreader is required, and the whale-oil or fish-oil soap commonly used must be heated to dissolve it, which causes delay and is a disagreeable task avoided when the dust is used.

With the dusting method, as with the spraying method, combination treatments for insects of different kinds, mites, and certain fungous diseases can be given, and for this purpose nicotine dust can be combined with powdered lead arsenate or dry sulphur.

WHAT IS NICOTINE DUST?

Nicotine dust is simply a certain amount of the standard solution of nicotine sulphate, containing 40 per cent nicotine, thoroughly

mixed with a dust carrier. This carrier must be fine, light, cheap, inert as far as action on foliage is concerned, and of a material with which the nicotine will mix freely but not become permanently absorbed.

Kaolin, the first material extensively used, was the best carrier in so far as the first four points are concerned, but was found to absorb and tie up some of the nicotine, making it unavailable for action on the insects. Two forms of lime are now used, namely, refuse lime from sugar-beet mills and pure hydrated lime. Finely ground sulphur is also used to a considerable extent for amounts up to about 70 per cent of the carrier.

In making the dust, regardless of what carrier is used, a certain amount of lime is added. A chemical reaction takes place, in which the nicotine is set free from the sulphate. The active ingredient in the finished product is therefore nicotine, which is more active than nicotine sulphate. Because of this reaction, and also because of the fact that the killing is done by the nicotine, the dust should be called nicotine dust rather than nicotine sulphate dust.

The use of powdered sulphur in the carrier along with the lime makes a more effective dust than when hydrated or sugar-beet lime alone is used, because the sulphur releases the nicotine more readily than does the lime, and therefore the nicotine-sulphur dust is more active than the nicotine-lime dust. By using from 10 to 40 per cent of sulphur in the carrier, the amount of the nicotine-sulphate solution added can be reduced at least 1 or 2 per cent, and the same results obtained as with the higher strengths in lime alone. Sulphur, on the other hand, is more difficult to pulverize than lime and is heavier. It is also unsuitable for use on melons and other cucurbits, which may be severely injured by it.

To insure killing all the insects, each particle of the dust should be impregnated with nicotine. This necessitates thorough mixing with the best machinery obtainable. As machinery is expensive, the dust is made almost entirely by commercial manufacturers, and sold ready to use. It would be entirely feasible, however, for large-scale growers and growers' associations, etc., to install the proper machinery and manufacture their own dust, at considerably less cost than the present retail price.

HOW TO PREPARE THE DUST.[1]

This dust can be made of the following combinations of materials, which act as carriers, to which the desired amount of nicotine sulphate is added: Kaolin and lime; sugar-beet lime and hydrated lime; hydrated lime; lime and finely ground sulphur. Various pro-

[1] Adapted from Department Circular 224, U. S. Dept. Agr., "Nicotine Dust for Control of the Striped Cucumber Beetle," by W. H. White.

portions of the different materials are used, of which the formulas given below are typical:

FORMULA No. 1.

Four per cent nicotine sulphate, equivalent to 1.6 per cent nicotine.

100-pound lots.		*12½-pound lots.*	
Kaolin ---------- pounds--	72	Kaolin ---------- pounds--	9
Hydrated lime ---------- do----	24	Hydrated lime ---------- do----	3
Nicotine sulphate ---------- do----	4	Nicotine sulphate ---------- ounces--	8

FORMULA No. 2.

Five per cent nicotine sulphate, equivalent to 2 per cent nicotine.

100-pound lots.		*12½-pound lots.*	
Hydrated lime ---------- pounds--	95	Hydrated lime ---------- pounds--	12
Nicotine sulphate ---------- do----	5	Nicotine sulphate ---------- ounces--	10

FORMULA No. 3.

Six per cent nicotine sulphate, equivalent to 2.4 per cent nicotine.

100-pound lots.		*12½-pound lots.*	
Hydrated lime ---------- pounds--	54	Hydrated lime ---------- pounds--	6¾
Finely-ground sulphur ---------- do----	40	Finely-ground sulphur ---------- do----	5
Nicotine sulphate ---------- do----	6	Nicotine sulphate ---------- ounces--	12

In the preparation of this dust it is very important that the nicotine sulphate be thoroughly mixed with the carrier. This can be accomplished by first mixing and sifting the materials composing the carrier, then combining the required amount of nicotine sulphate with the dust, adding the nicotine slowly and mixing all thoroughly. The nicotine sulphate can be added to the dust by the use of any convenient sprinkler. A pint fruit jar with a metal top from which the porcelain has been removed, punched with holes by the use of a 6-penny nail, makes a good sprinkler. After the addition of the nicotine sulphate the mixture should be run through a fine sieve, 20 meshes to the inch, with the aid of a brush. This last operation should be repeated at least three times. Be sure that all the material is worked through the sieve, since if this be neglected a large quantity of the nicotine may be lost.

A very satisfactory and simple method of mixing the dust consists of a box (Fig. 1) with a detached cover in which a sieve is placed and an ordinary floor brush with a handle is attached. A slot is cut in the side of the box so as to allow operation of the brush with the cover on. The cover to a large extent prevents the escape of the dust during the mixing process and consequent inconvenience to the operator.

The dimensions of a box in which 12½ pounds of the dust can be conveniently mixed are as follows: Length, 15 inches; width, 10 inches; depth, 12 inches.

The sieve is constructed of brass screen, 20 meshes to the inch, tacked to a frame 4 inches deep.

The sieve fits snugly inside of the box and rests on a strip 5½ inches from the upper edge of the box.

The brush is an ordinary floor brush with edge trimmed off so that the corners and edges of the sieve may be reached.

The handle, 20 inches in length, attached at right angles to the brush, is so constructed that the brush will rest in a level position over the entire length of the sieve and that the end of the handle will come through a slot in the upper end of the box.

If a large quantity of dust will be needed during the season, a mechanical mixer will be found more satisfactory than the home-

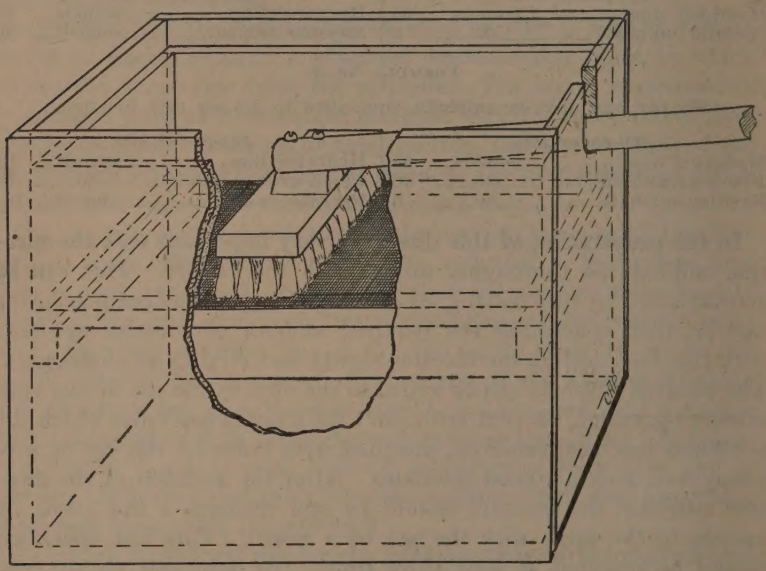

FIG. 1.—A mixer for use in preparation of small quantities of nicotine dust. (White.)

made one. A sifter and mixer such as is used by bakers can be procured in several sizes, any one of which will mix and sift the dust thoroughly, rapidly, and economically.

COMBINATIONS OF NICOTINE DUST WITH OTHER INSECTICIDES AND WITH FUNGICIDES.

It has long been the custom in spraying operations to combine two or more insecticides, or an insecticide and a fungicide, when different types of insects or a disease and an insect are infesting one plant. This practice can be continued to a large extent with dusting; in fact, some combinations are more satisfactory in the dust form than as sprays.

Powdery mildew is a common disease of peas which is most successfully combated with sulphur. The use of a nicotine-sulphur dust, in which the carrier is about 70 per cent finely ground sulphur, will control not only the mildew but also the pea aphis. In parts of southern California peas are damaged by the beet army worm [2] and by cutworms. These may be combated, especially when the insects are young, by including in the mixture 10 per cent of powdered arsenate of lead.

On cabbage, the nicotine dust will kill the aphis and also some cabbage worms, but if the latter are numerous, the nicotine-arsenate of lead combination may be used. This is also effective against flea-beetles on tomatoes.

Nicotine-sulphur dust should be used cautiously on cucumbers or melons, as more or less burning of the foliage may result, especially in very hot weather. This dust is partially effective against the red spider and is effective against mildew.

ACTION OF NICOTINE DUST.

The action of nicotine dust on insects is similar to that of nicotine sulphate in a liquid spray, i. e., nicotine fumes or vapors, entering the breathing pores of the insect, kill by paralyzing the nervous system. With the dust, this action becomes effective more quickly. Within a minute after the application, aphids and some other insects show evidence of extreme distress. Aphids elevate their abdomens as though trying to stand on their heads, and soon fall. Some beetles and small bugs lose the power of locomotion almost immediately, but continue to move their legs and antennæ convulsively for a few minutes before becoming completely paralyzed.

Because nicotine fumes are the active ingredient, killing is brought about in three ways: First, by covering, or partially covering, the body of the insect with dust; second, by covering the foliage or ground about the insect; third, by enveloping the whole plant with a cloud of dust which penetrates to all parts of the foliage. The first is obviously the surest method. With the material on the body of the insect, the nicotine fumes are certain to enter the spiracles, or breathing pores, causing almost instant death. The second and third methods, where the fumes suffocate or repel any insects in the immediate vicinity of the dust, are more like fumigation. As a matter of fact, in the usual dusting operation all three conditions are present. The mere making of a cloud of dust about the plant, however, is not sufficient. This cloud must be driven in and throughout the foliage in order to reach all the insects.

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[2] *Laphygma exigua* Hübn.

TIME OF APPLICATION.

Since the fumes of nicotine in this dust must be depended upon to kill the insects, two factors are of importance in its application, viz, the stillness of the air and the temperature. The longer the cloud of dust remains around the infested plant, the more likely the insects are to be killed by the fumes. On the other hand, if a wind is blowing, not only the cloud of dust itself, but the fumes also, will be blown away. Therefore it is desirable to apply the dust when the air is still. Usually this is early in the morning or just at dusk. At these times, also, the humidity being higher, the dust remains close to the ground.

The effectiveness of the dust is also dependent on the volatility of the nicotine, which is greatly increased at a high temperature, resulting in a much quicker and more thorough killing. Hence, from this standpoint alone, the application is best in the warmer portion of the day. If, however, a breeze is blowing, the value of the temperature may be entirely offset by the rapid diffusion of the fumes.

Dust should not be applied either when the wind is blowing or on a day when the outdoor temperature is much below 65° F.

NUMBER OF APPLICATIONS.

Such insects as aphids and thrips reproduce very rapidly. No matter what method of control is used, therefore, whether it be dusting or spraying, under conditions favorable to the insect a reinfestation may take place, even though a high percentage may have been killed. On this account it is not to be expected that at all times one dusting will be sufficient for an entire season. Sometimes one application will be sufficient, but it may be necessary to dust twice or even three times. In fact, many growers plan for a second application, timing it to check the second infestation before it begins to be serious.

All dusting and spraying should be done with the idea of preventing infestation and the resulting damage rather than trying to stop an infestation after it has become heavy. This is always the easier, cheaper, and more profitable way. If the grower waits until the field is quite generally infested before starting control measures, even though practically all the insects present are killed, it is probable that they will have already done considerable damage to the plants and reduced the crop accordingly. The grower, then, may feel that the control measures were not worth while, whereas, if they had been undertaken earlier, the damage would have been prevented and a larger crop produced.

STRENGTH OF NICOTINE TO USE.

Some of the smaller, frailer aphids, such as the walnut aphids, are easily controlled with a dust containing only 2 per cent by weight of nicotine sulphate solution, but the ordinary insect against which it is used requires at least 4 per cent. This amount, when carefully applied, will control most aphids and thrips. For ordinary commercial purposes a 5 per cent strength is most commonly used, and is to be recommended. For certain insects which are more resistant to the action of insecticides, from 6 to 8 per cent is required, and in some cases a 10 per cent strength is used. If the application is carefully and thoroughly made, the lesser strengths will do satisfactory work in most cases.

All formulas in this bulletin refer to the percentage by weight of the ordinary commercial solution of nicotine sulphate, which contains 40 per cent nicotine. As the nicotine only is the active ingredient, and is the material referred to by some writers, the difference in the two is as follows:

Percentage of the commercial solution of nicotine sulphate containing 40 per cent nicotine added to the dust.	Per cent of pure nicotine in the dust.
2	0.8
4	1.6
5	2.0
6	2.4
8	3.2
10	4.0

This is the theoretical amount of nicotine contained in the dust. As a matter of fact, some of the nicotine volatilizes during the mixing, and is lost. Although the manufacturer may put in the full amount of the nicotine-sulphate solution shown in the left-hand column, his guarantee of the amount of pure nicotine in the finished product will be somewhat less than the corresponding amount given in the right-hand column.

As nicotine is the killing agent, the buyer should ascertain which of the foregoing methods is used in labeling the dust, and he will avoid the mistake of buying a dust containing 4 per cent of the nicotine sulphate solution, thinking it contains 4 per cent pure nicotine.

LOSS OF STRENGTH.

Since the nicotine in this dust is very volatile some of the killing power is likely to be lost if the dust is held for any length of time in open containers. When first used the dust was put up in burlap sacks with paper liners, and, as it was used within a short time, there was little or no loss of strength. It is the present practice to put up practically all the dust in air-tight containers, such as sheet-iron drums, but even in these it is not advisable to hold the dust longer

than necessary. The grower should buy or make his dust only for immediate needs. It should be the policy of dealers to keep on hand just enough freshly made dust to keep ahead of the needs of customers, and manufacturers should make the dust only as ordered. This will insure a supply of freshly made, active dust which, when applied as directed, will control many of the pests that damage truck crops.

TYPES OF DUSTING MACHINERY.

Several types of dusting machines are now available, from small hand dusters, adequate only for small back-yard gardens, to large power-driven outfits, suitable for extensive acreages.

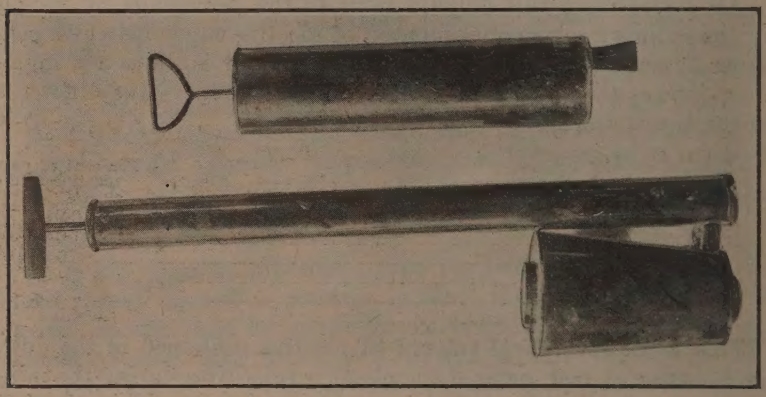

FIG. 2.—Two types of small hand dusters suitable for backyard gardens.

HAND DUSTERS.

Figure 2 shows two types of small hand dusters suitable only for very small areas, such as home gardens or a few ornamental plants. These machines have no feed regulator and the dust application is not entirely uniform. No attempt should be made to use them except on an area of a few dozen plants. They retail at about $1 each.

For smaller commercial acreages there are two types of hand dusters which do very satisfactory work. One, the hand-operated bellows duster (Fig. 3; Fig. 14, at right) was found best adapted to plants, such as cucumbers and melons, grown in hills. The dust is applied in puffs, as the air is forced from the bellows. The dust feed can be regulated, both as to quantity and as to its fineness or coarseness. These dusters are also well adapted for use on small trees, vines, and shrubs. An average maximum of 2 acres can be covered in a day with one of these machines under favorable conditions. They weigh from 15 to 20 pounds each and the capacity of the hopper is ap-

proximately the same weight of dust. The machine is carried strapped on the back of the operator. The cost is from $17 to $20 each.

The other type of hand machine, the blower gun (Fig. 6; Fig. 14, at left), in which the air pressure is supplied by a rapidly revolving fan, is operated by a hand crank and gears. The flow of dust is continuous, and the amount can be regulated by an adjustable feeding device. This type of machine is particularly adapted to row crops, as the continuous flow permits the operator to keep up a steady walk alongside the row, directing the cloud of dust so as to cover it com-

FIG. 3.—Hand-operated bellows type of duster used in applying nicotine dust to melons for the melon aphis.

pletely. Since no time is lost between puffs, the blower gun will cover a somewhat larger acreage than the bellows type, but will use a little more material per acre.

Both types of hand dusters, and especially the blower gun, are rather laborious to operate. It has been demonstrated on small plots that almost 1 acre per hour can be covered with this type of duster, but such a pace can not be maintained for any length of time. Partly because of the toilsomeness of the operation, and more particularly because of the desirability of making the application when the air is still, the practice has arisen of applying the dust only for a few hours in the morning or evening. The average ground covered daily would not be over 4 acres. Hand-blower guns weigh about 10 or 12 pounds

and have a hopper capacity of 6 or 8 pounds of dust. Most of them are carried resting against the abdomen, with straps over the shoulders. The retail price of these machines is from $15 to $25 each.

HORSE-DRAWN DUSTERS.

The one-horse duster is a new type developed in the South in response to the demand for a machine intermediate between the hand and power outfits for use in combating the boll weevil. Many farmers had acreages too large to be economically covered by hand machines, yet too small to warrant the expense of a power outfit. The situation has been the same in the development of methods of applying nicotine dust; i. e., there has been a demand for an inexpensive, intermediate machine which will cover up to 10 acres a day, and can be operated by a horse and one man. The essential features of these machines are: A large hopper with a capacity of 50 to 60 pounds of dust, a positive and easily regulated dust-feeding device, a high-speed fan, and a set of discharge pipes to deliver the dust to two rows of plants. A single traction wheel runs between the rows, and through a series of gears supplies power to operate the revolving fan. A clutch on the main shaft of the wheel permits it to be released so that all working parts of the machine stop when it is being moved to or from the field.

Recent tests with the one-horse duster in applying nicotine dust to truck crops indicate that it is very well adapted to such work, but the machine must have a feeding device capable of delivering up to 60 or 75 pounds of dust per acre. Figures 7, 8, and 9 show one of these machines being used against the pea aphis. Crops like cabbage and peas can be gone over with such a duster at the rate of from 10 to 15 acres a day. The one-horse duster retails at from $100 to $150.

A larger machine having two wheels and drawn by two horses operates on the same principle, but is capable of covering almost double the acreage. This machine has not been used for nicotine dusting, but should be suitable for an acreage larger than that covered by the one-horse duster, and where the power outfit is not desired. These machines retail at from $250 up.

POWER DUSTERS.

The power duster, while used more extensively on fruit trees, is well adapted to truck crops. In the machine commonly used, the hopper holds about 100 pounds of dust. A mechanical and easily regulated device allows the desired amount of dust to feed into the discharge pipe through which the air is blown from a rapidly revolving fan. The latter is attached by means of a belt to a 2-horsepower gasoline engine. For certain occasions the single large

tree-dusting hose can be used, and the dust blown out over considerable areas of the crop. This is sometimes desirable in crops grown in plots (see Fig. 10) or where the plants are so large that to drive down the rows would do considerable damage. This is also a good method of application for such plants as melons or cucumbers.

A small power outfit with two discharge pipes, used successfully in controlling an infestation of the melon aphis in a casaba field, is shown in Figure 4. It covers the field at a rate of 1 acre an hour, using from 50 to 75 pounds of dust. The feed can be regulated so that any amount per acre desired can be applied. The machine should be elevated somewhat, preferably on a small wagon rather

FIG. 4.—Power-operated fan duster used with success in a badly infested melon field.

than on a sled. This outfit, with engine, costs about $150, while the larger outfit is retailed at $350.

The most satisfactory method of dust distribution from power outfits for truck crops grown in rows is through a series of pipes, covering six or eight rows at a time. For some crops the pipes are adjusted to shoot directly down on the rows, a pipe to each row, while on others the pipes hang down between the rows close to the ground and discharge the dust at right angles, toward the rows on each side. The first type is best for plants where the infestation is in the upper leaves, or where it is necessary to drive the dust directly down into the plants, while the second type has been found most satisfactory where it is desirable to direct the dust toward the underside of the leaves. Such a machine will cover about 4 acres an hour. Figures

12 and 13 show one in operation against the onion thrips in the Coachella Valley.

THE MELON APHIS.[3]

The melon aphis is a serious enemy of melons, squash, cucumber, cotton, and several other crops, the damage varying from year to year, and in different localities, from slight and scattered infestations of little consequence to severe infestations causing a total loss of the crop. As these insects feed almost entirely on the lower surface of the leaves, frequently causing them to curl, it is difficult to obtain satisfactory control with a liquid spray. If sufficient time and care are taken to insure the covering of all leaves, particularly the underside, the operation becomes too expensive, and if such care is not taken the percentage of aphids killed is too low to make spraying worth while.

A cloud of fine dust blown into the plant and hovering over and about it, however, penetrates to all parts of the foliage, coming in contact with the underside, and even into the curled leaves. This is especially true when the end of the discharge pipe is placed in the midst of the foliage, and with a spoon-shaped nozzle attachment by which the cloud of dust is directed upward, to the under surface of the leaves.

Since melons, cucumbers, etc., are usually grown in hills, and it is desirable in dusting them to pay special attention to directing the blast of dust, the bellows type of hand duster (Fig. 3; Fig. 14, at right) is very satisfactory for this work. With such a machine one man can cover up to 2 acres of full-grown melons or cucumbers a day, using up to 50 pounds of dust per acre. On smaller plants a greater acreage can be covered, and with less dust.

It is characteristic of the melon aphis to appear early in the season, when the plants are small, and often to infest plants seriously here and there in the field. If left unchecked, these plants will be sufficiently damaged to produce little or no fruit, and the aphids are likely to spread to all parts of the field. Such scattered infestations are troublesome to spray with a large outfit, while knapsack or small compressed-air sprayers are almost equally unsatisfactory. With a duster of the type shown in Figure 3, however, it is easy and inexpensive to go over the field as often as necessary, dusting the infested plants, and thus not only killing the aphids in these early infestations and stopping the damage to the young plants, but also preventing the aphids from spreading and infesting the entire field.

The small power outfit shown in Figure 4 can be used on large acreages of well-grown plants, or where it is desirable to get over

[3] *Aphis gossypii* Glover.

a field quickly. It will dust a melon field at the rate of almost 1 acre per hour, but is likely to use more dust than the hand machines.

Dusting for this aphis was found to be satisfactory on all kinds of melons, cucumber, and squash.

THE CABBAGE APHIS.[4]

The cabbage aphis, a cosmopolitan and widely distributed pest, which often causes serious damage to cabbage, kale, cauliflower, turnips, and related crops, is not infrequently held in check by cold weather or driving rains, but in many seasons, when there is a lack

FIG. 5.—Dusting for the cabbage aphis. Note cloud of dust completely covering all parts of infested plants.

of these conditions, the insects multiply very rapidly, which results in serious infestations and heavy damage to thousands of acres of cabbage and cauliflower.

As with the melon aphis, it is difficult to obtain a satisfactory killing of the cabbage aphis by spraying, because the colonies of aphids are usually on the underside of the leaves, or are protected by the compact foliage of the growing head. Further, the aphis colonies cause the leaves to curl, rendering it almost impossible to reach them with spray. But the cloud of dust blown into the plant entirely surrounds it, and the fine particles drift in among the infested leaves, reaching a large percentage of the aphids (see Fig. 5).

[4] (*Aphis*) *Brevicoryne brassicae* L.

Extensive experiments showed that a dust containing less than 4 per cent of commercial nicotine-sulphate solution did not secure an efficient killing, and also that the slight increase in the percentage killed with strengths above 6 per cent did not justify the increased cost of the extra nicotine sulphate. It was determined that for ordinary commercial purposes, a 5 per cent strength was most satisfactory, considering both the killing obtained and the cost per pound.

The following figures, showing the cost of dusting, were furnished by a cabbage grower, who successfully checked an infestation of this aphis in his fields, using the hand dusters described:

On cabbage less than half grown:	
Dust, 30 pounds, at 15 cents	$4.50
Labor at $3.25 per day	1.65
Total cost per acre	6.15
On cabbage over half grown:	
Dust, 50 pounds, at 15 cents	7.50
Labor at $3.25 per day	1.85
Total cost per acre	9.35

With a one-horse duster it is possible to cover a little over an acre of infested cabbages an hour, applying any desired amount of dust up to about 60 pounds per acre. While this machine is more wasteful of material than the hand dusters, its greater speed considerably reduces the cost of application, as shown by the following:

300 pounds dust, at 15 cents	$45.00
One man and horse, per day	5.00
Total cost for 10 acres	50.00
Total cost per acre	5.00

This gives a cost of $5 per acre, as compared with $6.15 with the hand machines.[5]

THE PEA APHIS.[6]

The pea aphis is well distributed over nearly the entire country, and under favorable conditions multiplies with great rapidity, causing severe losses to the pea crop. This happens far too often to suit the pea grower, who, in order to prevent this loss, must adopt control measures. In many localities the growing of peas has been largely abandoned because of the regular appearance of this pest. All forms of peas and sweet peas, as well as other legumes, are subject to attack.

[5] The price of nicotine dust has been high, but, due partly to adjustment of economic conditions and particularly to greater competition in its manufacture and sale, the price will undoubtedly be lowered somewhat another season. Labor prices may also be lower. Therefore, in figuring the cost of dusting the local price of both labor and dust must be considered, as they will probably differ from those given in this bulletin.

[6] (*Macrosiphum*) *Illinoia pisi* Kalt.

The pea aphis is considerably larger than most other aphids and is more resistant to insecticides. In both liquid spraying and dusting a higher strength of nicotine is required for effectiveness than is ordinarily used. Not less than a 6 per cent strength of dust should be used, while many growers prefer 10 per cent. Several large seed companies in California have used the 10 per cent strength on their sweet peas for three seasons, and are much better satisfied with the results than with any previous control work with liquid sprays.

All types of dusters employed were used with success on peas. For a hand duster, the fan type is very satisfactory, as the con-

FIG. 6.—Hand-operated fan duster in use against the pea aphis.

tinuous flow of dust permits the operator to make the application at a steady walk, holding the discharge pipe directly over the row (Fig. 6; Fig. 14, at left). It may use a little more dust than the bellows type, but will cover the acreage much more rapidly, at least 1 acre more a day.

One-horse dusters in operation in a pea field are shown in Figures 7, 8, and 9. Under average conditions a machine of this type will cover about 1 acre an hour. A power outfit with a single discharge hose used successfully in plots of sweet peas is shown in Figure 10. Until the peas are large it is better to use the discharge pipes similar to those in Figures 12 and 13. Such outfits are used by several

large seed companies in California, applying as high as 100 pounds per acre of a 10 per cent dust and covering 3 to 4 acres per hour.

FIG. 7.—Treating a pea field infested by pea aphis with a one-horse duster.

FIG. 8.—One-horse type of duster in use against pea aphis.

Because of the present high cost of the dust and the fact that a high percentage of nicotine is required to effect control, dusting for the pea aphis can only be applied to especially valuable crops.

such as high-priced market peas or sweet peas, and will probably prove too expensive for cannery or low-priced market peas.

FIG. 9.—One-horse duster in use against pea aphis.

THE ONION THRIPS.[7]

The onion thrips, also an insect of wide distribution, is the cause of enormous damage to onions practically wherever the latter are

FIG. 10.—Power-operated duster with single discharge pipe, used in field of sweet peas when plants are too large to permit driving down the rows.

grown. It is also very destructive to cauliflower, cabbage, cucumber, and melons, and various other vegetables. Spraying is efficient in controlling it from the standpoint of the percentage killed, but

[7] *Thrips tabaci* Lind.

some growers object to it because of damage to closely planted rows from horse-drawn vehicles, the necessity of often going some distance for water, the inconvenience and delay of heating the soap, and because of the weight of the water which must be transported across the field. The use of nicotine dust also gives a satisfactory killing of the onion thrips, but its application involves none of the objectionable features of liquid spraying.

The hand-operated dusters (Fig. 11) will cover from 2½ to 3 acres a day, using from 30 to 50 pounds of dust per acre. A small power-operated duster, treating six rows at a time, was capable of covering 10 to 12 acres a day.

FIG. 11.—Dusting onions infested by onion thrips with hand-operated bellows duster.

One grower, anticipating the need of control measures, planted a large field of onions in triplicate rows, i. e., in sets of three rows 4 inches apart, with every two such sets 30 inches apart. This arrangement not only permits the use of the desired machinery for controlling the thrips, but actually makes it possible to grow about one-third more onions to the acre. A power outfit was placed on a wagon or truck, with a set of eight discharge pipes at the back, covering as many triplicate rows, or sets, with a pipe to each set of three rows. Figures 12 and 13 show the duster in action. With this it was possible to cover as much as 4 acres per hour. The most satisfactory control was obtained by using the 5 per cent strength, and up to 40 pounds per acre for the larger onions. When the air is quiet, and the dust does not drift away quickly, a smaller amount is sufficient.

CUCUMBER BEETLES.[8]

Cucumber beetles cause considerable damage each season, not only to cucumber, squash, melons, and other cucurbits, but also to a variety of plants. Although biting insects of a type ordinarily best controlled by a stomach poison, they are easily overcome by the fumes of nicotine dust, especially when they attack young cucumber or squash plants. Using the hand-operated bellows duster (Fig. 14, at right) with a liberal feed, one or two puffs of dust are sufficient to cover a hill. Since the beetles are apt to fly when disturbed, the first blast of dust must be sufficiently liberal to coat the beetles thoroughly, otherwise they may escape.

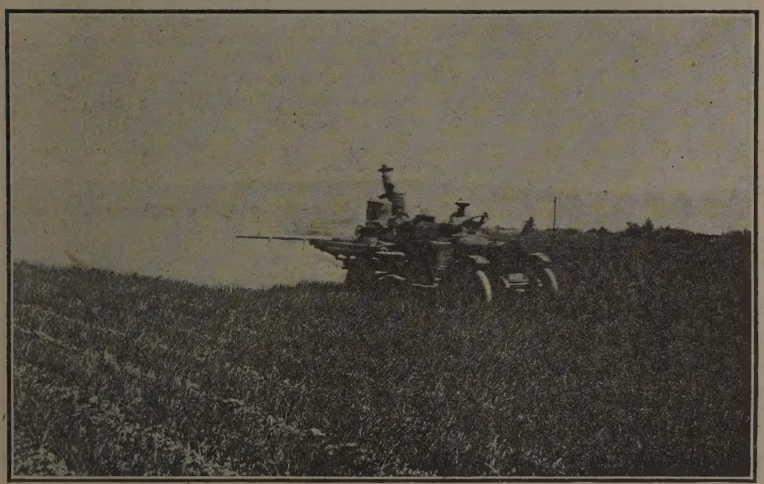

FIG. 12.—Dusting onions for onion thrips with a power duster mounted on a truck; front view.

Not less than a 6 per cent strength should be used, and many growers prefer the 10 per cent mixture, as it is much more sure to overcome the beetles with the first puff of dust.

On small cucumbers, 1 pound of dust will cover from 200 to 300 hills, at the rate of nearly 1,000 hills per hour. On larger plants, the applications are similar to those for the melon aphis, except that it is not necessary to make the application so that the underside of all the leaves is reached.

It has been found advisable when applying this dust to small plants for cucumber beetles to add to the carrier 10 per cent of powdered

[8] *Diabrotica* spp. The nicotine-dust treatment has been used by the writer against the western twelve-spotted cucumber beetle (*Diabrotica soror* Lec.) and the western striped cucumber beetle (*D. trivittata* Mann.) in California, and by W. H. White, Bureau of Entomology, against the striped cucumber beetle (*D. vittata* Fab.) in the East. (See Department Circular 154, U. S. Dept. Agr., 1921, and Department Circular 224, U. S. Dept. Agr., 1922.)

arsenate of lead. This will take care of any beetles which may infest the plants after the nicotine has lost its effectiveness.

OTHER INSECTS.

Other insects against which this dust has proved entirely satisfactory on a small scale, but against which no extensive work has been done, are the bean aphis,[9] the artichoke aphis,[10] the rose aphis,[11] the false chinch bug,[12] the bean thrips,[13] young or immature grasshoppers, and several kinds of hairy caterpillars in their earlier stages.

FIG. 13.—Large power-operated duster for applying dust to combat onion thrips; rear view.

Very recent tests of this dust against the spotted garden slug[14] killed 100 per cent, even when they were only lightly dusted.

DISADVANTAGES OF NICOTINE DUST.

Nicotine dust is by no means a perfect insecticide, being subject to the following disadvantages:

Its volatility causes it to lose strength rapidly, so that unless put up in air-tight containers it must be used promptly after manufacture.

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[9] *Aphis rumicis* L.
[10] *Myzus braggii* Gillette.
[11] *Macrosiphum rosae* L. and *Aphis rosarum* Walk.
[12] *Nysius ericae* Schill.
[13] *Heliothrips fasciatus* Perg.
[14] *Limax maximus* L.

The dust is sometimes disagreeable to the operator, especially if the latter is inexperienced in applying it.

It can not be combined with Bordeaux mixture, except when the latter is dry.

It can not be applied satisfactorily in windy or cold weather.

Its present cost [15] per pound is high.

FIG. 14.—Two types of hand-operated dusters used in an infested pea field: At left, fan type; at right, bellows type.

SUMMARY.

For controlling certain truck-crop insects nicotine dust has several advantages over a liquid spray of nicotine sulphate. Dusting requires much less weight of material per acre, and may be done in a much shorter time with a lighter and less expensive machine, and in most cases at less cost. The tiny particles of dust reach many insects inaccessible to sprays.

Nicotine dust is nicotine-sulphate solution mixed in correct proportion with a dust carrier. Lime alone is ordinarily used for the carrier, but the addition of sulphur to the lime makes the material more effective against most insects.

Nicotine dust kills the insects by paralyzing the nervous system almost immediately. The application should be thorough in order that the dust may come in contact with as many insects as possible.

Dust may be applied with hand dusters for small acreages, horse-drawn outfits for larger acreages, and power-operated outfits for extensive acreages.

[15] In the year 1922.

Nicotine dust is most effective at temperatures above 65° F., and when the air is still.

For ordinary uses, a dust containing 2 per cent of nicotine is the most satisfactory.

Among the insects satisfactorily controlled with this dust are the melon aphis, the cabbage aphis, the pea aphis, the onion thrips, and cucumber beetles.

Certain diseases, as well as certain insects of truck crops, can be controlled by adding a proportion of powdered sulphur to the nicotine dust used against the insects.

Certain chewing insects attacking truck crops can be controlled by adding 10 per cent of powdered lead arsenate to the nicotine dust used against aphids or thrips, and this combination treatment is advisable when dusting small plants for cucumber beetles.

Several applications may be necessary. These should be made early, i. e., when the insects first appear, before any damage is done.

Nicotine dust loses strength if held for any length of time, or if not put up in air-tight containers. It is likely to be ineffective if applied on a windy or cold day.

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